

CLAIMS

1 1. (original) A method for processing audio signals, comprising:
2 receiving a plurality of audio signals, each audio signal having been generated by a different
3 sensor of a microphone array; and
4 decomposing the plurality of audio signals into a plurality of eigenbeam outputs, wherein each
5 eigenbeam output corresponds to a different eigenbeam for the microphone array and at least one of the
6 eigenbeams has an order of two or greater.

1 2. (original) The invention of claim 1, wherein the eigenbeams correspond to spheroidal
2 harmonics based on a spherical, oblate, or prolate configuration of the sensors in the microphone array.

1 3. (original) The invention of claim 1, wherein at least one of the eigenbeams has an order
2 of at least three.

1 4. (original) The invention of claim 1, wherein the microphone array comprises the
2 plurality of sensors mounted on an acoustically rigid sphere.

1 5. (original) The invention of claim 4, wherein one or more of the sensors are pressure
2 sensors.

1 6. (original) The invention of claim 5, wherein at least one pressure sensor comprises a
2 patch sensor operating as a spatial low-pass filter to avoid spatial aliasing resulting from relatively high
3 frequency components in the audio signals.

1 7. (original) The invention of claim 6, wherein at least one patch sensor comprises a
2 number of proximally configured, individual pressure sensors, wherein, for each such patch sensor,
3 analog signals generated by the number of individual pressure sensors are combined before sampling to
4 generate a digital audio signal for that patch sensor.

1 8. (previously presented) The invention of claim 6, wherein the at least one pressure sensor
2 further comprises a point sensor, wherein:
3 the point sensor is used to generate relatively low frequency audio signals; and
4 the patch sensor is used to generate relatively high frequency audio signals.

1 9. (original) The invention of claim 4, wherein one or more of the sensors are elevated over
2 the surface of the sphere.

1 10. (currently amended) The invention of claim 1, wherein the microphone array comprises
2 the plurality of sensors mounted on an acoustically soft sphere comprising a gas-filled elastic shell such
3 that impedance to sound propagation through the acoustically soft sphere is less than impedance to sound
4 propagation through liquid medium outside of the sphere.

1 11. (original) The invention of claim 10, wherein one or more of the sensors are cardioid
2 sensors configured with their nulls pointing towards the center of the sphere.

1 12. (original) The invention of claim 1, wherein the number and positions of sensors in the
2 microphone array enable representation of a beampattern as a series expansion involving at least
3 second-order spheroidal harmonics.

1 13. (original) The invention of claim 12, wherein the number of sensors is based on the
2 highest-order spheroidal harmonic in the series expansion.

1 14. (original) The invention of claim 1, wherein the arrangement of the sensors in the
2 microphone array satisfies a discrete orthogonality condition.

1 15. (original) The invention of claim 1, wherein decomposing the plurality of audio signals
2 further comprises treating each sensor signal as a directional beam for relatively high frequency
3 components in the audio signals.

1 16. (original) The invention of claim 1, further comprising generating an auditory scene
2 based on the eigenbeam outputs and their corresponding eigenbeams.

1 17. (original) The invention of claim 16, wherein generating the auditory scene comprises
2 independently generating two or more different auditory scenes based on the eigenbeam outputs and their
3 corresponding eigenbeams.

1 18. (original) The invention of claim 16, wherein generating the auditory scene comprises:
2 applying a weighting value to each eigenbeam output to form a weighted eigenbeam; and

3 combining the weighted eigenbeams to generate the auditory scene.

1 19. (original) The invention of claim 1, further comprising storing data corresponding to the
2 eigenbeam outputs for subsequent processing.

3
1 20. (original) The invention of claim 19, further comprising:
2 recovering the eigenbeam outputs from the stored data; and
3 generating an auditory scene based on the recovered eigenbeam outputs and their corresponding
4 eigenbeams.

1 21. (original) The invention of claim 1, further comprising transmitting data corresponding
2 to the eigenbeam outputs for remote receipt and processing.

1 22. (original) The invention of claim 21, further comprising:
2 recovering the eigenbeam outputs from the received data; and
3 generating an auditory scene based on the recovered eigenbeam outputs and their corresponding
4 eigenbeams.

1 23. (original) The invention of claim 1, further comprising applying an equalizer filter to
2 each eigenbeam output to compensate for frequency dependence of the corresponding eigenbeam.

1 24. (original) The invention of claim 1, wherein receiving the plurality of audio signals
2 further comprises generating the plurality of audio signals using the microphone array.

1 25. (original) The invention of claim 24, wherein receiving the plurality of audio signals
2 further comprises calibrating each sensor of the microphone array based on measured data generated by
3 the sensor.

1 26. (original) The invention of claim 25, wherein receiving the plurality of audio signals
2 comprises calibrating each sensor of the microphone array using a calibration module comprising a
3 reference sensor and an acoustic source configured on an enclosure having an open side, wherein the
4 open side of the volume is held on top of the sensor in order to calibrate the sensor relative to the
5 reference sensor.

1 27. (original) The invention of claim 1, wherein the plurality of sensors are arranged in two
2 or more concentric arrays of sensors, wherein each array is adapted for audio signals in a different
3 frequency range.

1 28. (original) The invention of claim 27, wherein audio signals from different arrays are
2 combined prior to being decomposed into a plurality of eigenbeams.

1 29. (original) The invention of claim 1, wherein all of the sensors are used to process
2 relatively low-frequency signals, while only a subset of the sensors are used to process relatively
3 high-frequency signals.

1 30. (original) The invention of claim 29, wherein only one of the sensors is used to process
2 the relatively high-frequency signals.

1 31. (original) A microphone, comprising a plurality of sensors mounted in an arrangement,
2 wherein the number and positions of sensors in the arrangement enable representation of a beampattern
3 for the microphone as a series expansion involving at least one second-order eigenbeam.

1 32. (original) The invention of claim 31, wherein the series expansion involves an
2 eigenbeam having order of at least three.

1 33. (original) The invention of claim 31, wherein the arrangement is one of spherical,
2 oblate, or prolate.

1 34. (original) The invention of claim 31, wherein the plurality of sensors are mounted on an
2 acoustically rigid sphere.

1 35. (original) The invention of claim 34, wherein the sensors are pressure sensors.

1 36. (original) The invention of claim 35, wherein at least one pressure sensor comprises a
2 patch sensor operating as a spatial low-pass filter to avoid aliasing resulting from relatively high
3 frequency components in the audio signals.

1 37. (original) The invention of claim 36, wherein at least one patch sensor comprises a
2 number of proximally configured, individual pressure sensors, wherein, for each such patch sensor,
3 analog signals generated by the number of individual pressure sensors are combined before sampling to
4 generate a digital audio signal for that patch sensor.

1 38. (previously presented) The invention of claim 36, wherein the at least one pressure
2 sensor further comprises a point sensor, wherein:
3 the point sensor is used to generate relatively low frequency audio signals; and
4 the patch sensor is used to generate relatively high frequency audio signals.

1 39. (original) The invention of claim 34, wherein one or more of the sensors are elevated
2 over the surface of the sphere.

1 40. (currently amended) The invention of claim 31, wherein the plurality of sensors are
2 mounted on an acoustically soft sphere comprising a gas-filled elastic shell such that impedance to sound
3 propagation through the acoustically soft sphere is less than impedance to sound propagation through
4 liquid medium outside of the sphere.

1 41. (original) The invention of claim 40, wherein the sensors are cardioid sensors
2 configured with their nulls pointing towards the center of the sphere.

1 42. (original) The invention of claim 31, wherein the second-order eigenbeam corresponds
2 to a second-order spheroidal harmonic.

1 43. (original) The invention of claim 42, wherein the number of sensors is based on the
2 highest-order spheroidal harmonic in the series expansion.

1 44. (original) The invention of claim 31, wherein the arrangement of the sensors satisfies a
2 discrete orthogonality condition.

1 45. (original) The invention of claim 31, further comprising a processor configured to
2 decompose a plurality of audio signals generated by the sensors into a plurality of eigenbeam outputs,
3 wherein each eigenbeam output corresponds to a different eigenbeam for the microphone array and at
4 least one of the eigenbeams has an order of two or greater.

1 46. (original) The invention of claim 45, wherein the processor is further configured to
2 generate an auditory scene based on the eigenbeam outputs and their corresponding eigenbeams.

1 47. (original) The invention of claim 31, wherein the plurality of sensors are arranged in two
2 or more concentric arrays of sensors, wherein each array is adapted for audio signals in a different
3 frequency range.

1 48. (original) The invention of claim 47, wherein the sensors in the different arrays are
2 located at the same spherical coordinates.

1 49. (original) The invention of claim 31, wherein all of the sensors are used to process
2 relatively low-frequency signals, while only a subset of the sensors are used to process relatively
3 high-frequency signals.

1 50. (original) The invention of claim 49, wherein only one of the sensors is used to process
2 the relatively high-frequency signals.

1 51. (original) A method for generating an auditory scene, comprising:
2 receiving eigenbeam outputs, the eigenbeam outputs having been generated by decomposing a
3 plurality of audio signals, each audio signal having been generated by a different sensor of a microphone
4 array, wherein each eigenbeam output corresponds to a different eigenbeam for the microphone array and
5 at least one of the eigenbeam outputs corresponds to an eigenbeam having an order of two or greater; and
6 generating the auditory scene based on the eigenbeam outputs and their corresponding
7 eigenbeams.

1 52. (original) The invention of claim 51, wherein generating the auditory scene comprises:
2 applying a weighting value to each eigenbeam output to form a weighted eigenbeam; and
3 combining the weighted eigenbeams to generate the auditory scene.

1 53. (original) The invention of claim 51, wherein generating the auditory scene further
2 comprises applying an equalizer filter to each eigenbeam output to compensate for frequency dependence
3 of the corresponding eigenbeam.

1 54. (original) The invention of claim 51, wherein the microphone array comprises a
2 plurality of sensors mounted in a spheroidal arrangement.

1 55. (original) The invention of claim 54, wherein the plurality of sensors are mounted on an
2 acoustically rigid sphere.

1 56. (original) The invention of claim 55, wherein the sensors are pressure sensors.

1 57. (original) The invention of claim 56, wherein at least one pressure sensor comprises a
2 patch sensor operating as a spatial low-pass filter to avoid aliasing resulting from relatively high
3 frequency components in the audio signals.

1 58. (original) The invention of claim 57, wherein at least one patch sensor comprises a
2 number of proximally configured, individual pressure sensors, wherein, for each such patch sensor,
3 analog signals generated by the number of individual pressure sensors are combined before sampling to
4 generate a digital audio signal for that patch sensor.

1 59. (previously presented) The invention of claim 57, wherein the at least one pressure
2 sensor further comprises a point sensor, wherein:

3 the point sensor is used to generate relatively low frequency audio signals; and

4 the patch sensor is used to generate relatively high frequency audio signals.

1 60. (original) The invention of claim 55, wherein one or more of the sensors are elevated
2 over the surface of the sphere.

1 61. (currently amended) The invention of claim 54, wherein the plurality of sensors are
2 mounted on an acoustically soft sphere comprising a gas-filled elastic shell such that impedance to sound
3 propagation through the acoustically soft sphere is less than impedance to sound propagation through
4 liquid medium outside of the sphere.

1 62. (original) The invention of claim 61, wherein one or more of the sensors are cardioid
2 sensors configured with their nulls pointing towards the center of the sphere.

1 63. (original) The invention of claim 54, wherein the number and positions of sensors in the
2 microphone array enable representation of a beampattern as a series expansion involving at least
3 second-order spheroidal harmonics.

1 64. (original) The invention of claim 63, wherein the number of sensors is based on the
2 highest-order spheroidal harmonic in the series expansion.

1 65. (original) The invention of claim 54, wherein the arrangement of the sensors satisfies a
2 discrete orthogonality condition.

1 66. (original) The invention of claim 51, wherein generating the auditory scene further
2 comprises treating each sensor signal as a directional beam for relatively high frequency components in
3 the audio signals.

1 67. (original) The invention of claim 51, wherein receiving the eigenbeam outputs further
2 comprises recovering the eigenbeam outputs from data stored during previous processing.

1 68. (original) The invention of claim 51, wherein receiving the eigenbeam outputs further
2 comprises recovering the eigenbeam outputs from data received after transmission from a remote node.

1 69. (original) The invention of claim 51, wherein the number of higher-order eigenbeams
2 used in generating the auditory scene is limited to maintain a minimum value of signal-to-noise ratio
3 (SNR).

1 70. (original) The invention of claim 69, wherein the SNR is characterized using white noise
2 gain.

1 71. (original) The invention of claim 51, wherein generating the auditory scene comprises
2 independently generating two or more different auditory scenes based on the eigenbeam outputs and their
3 corresponding eigenbeams.

1 72. (original) The invention of claim 51, wherein the plurality of sensors are arranged in two
2 or more concentric patterns, each pattern having a plurality of sensors adapted to process signals in a
3 different frequency range.

1 73. (original) The invention of claim 72, wherein the sensors arranged in the innermost
2 patterns are mounted on the surface of an acoustically rigid sphere.

1 74. (original) The invention of claim 51, wherein all of the sensors are used to process
2 relatively low-frequency signals, while only a subset of the sensors are used to process relatively
3 high-frequency signals.

1 75. (original) The invention of claim 74, wherein only one of the sensors is used to process
2 the relatively high-frequency signals.

1 76. (previously presented) The invention of claim 16, wherein:
2 the auditory scene is a second-order or higher directional beam steered in a specified direction;
3 and
4 generating the auditory scene comprises:
5 receiving the specified direction for the directional beam; and
6 generating the directional beam by combining the eigenbeam outputs based on the
7 specified direction.

1 77. (previously presented) The invention of claim 46, wherein:
2 the auditory scene is a second-order or higher directional beam steered in a specified direction;
3 and
4 the processor is further configured to generate the auditory scene by:
5 receiving the specified direction for the directional beam; and
6 generating the directional beam by combining the eigenbeam outputs based on the
7 specified direction.

1 78. (previously presented) The invention of claim 51, wherein:
2 the auditory scene is a second-order or higher directional beam steered in a specified direction;
3 and
4 generating the auditory scene comprises:
5 receiving the specified direction for the directional beam; and
6 generating the directional beam by combining the eigenbeam outputs based on the
7 specified direction.